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ORIGINAL PAPER

Distribution of the potential and concentration of electrons in low-temperature plasma with hollow microparticles

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Abstract Using approximation of a uniform background (the jellium model) for a condensed dispersed phase, the analytical expressions describing a spatial distribution of the potential of the electric field and electron concentration in the low-temperature plasma at equilibrium which contains hollow spherical microparticles are obtained. The influence of heating temperature of plasma on the above distributions is studied, and the dependencies of the charge on microparticle radius, the size of the microparticle cavity and the absolute temperature of plasma are calculated. It is shown that electrons can be emitted not only into the surrounding plasma but also into the cavity of the particles.

Keywords Dusty plasma · Hollow particle · Jellium model

Introduction

Low-temperature plasma which contains small particles, or so-called dusty plasma, is a complex system with variation of the dust particle's charge, mass and size within plasma space distribution and time evolution (Fortov et al. 2004; Fortov et al. 2012; Shukla and Mamun 2002; Vladimirov et al. 2005; Couedel et al. 2010). Dusty plasma can be found in interplanetary space, comet tails and Earth's atmosphere (Shukla and Mamun 2002), as well as it accompanies many technological processes such as dc and rf discharges and solid-fuel combustion products. (Thomas 2009; Valderrama et al. 2010). Dust particles may be purposely introduced to plasma or may be formed in it spontaneously.

The interest in the dusty plasma has been raised significantly during the last decades, and the quantity of publications in the period from 1981 to 2004 increased exponentially with the e-folding time of 3.9 years (Merlino 2005). Such a significant growth of publications on this subject was driven primarily by discoveries in two different areas of research which are considered as the milestone events in dusty plasma physics. In planetary science, it was discovered the spokes in Saturn's B ring (Smith et al. 1982). In applied plasma science, it was shown that the contamination of semiconductor material in plasma processing tools was due to particles grown in the plasma (Selwyn et al. 1990). The above discoveries gave an impetus to a number of other research works in both basic and applied plasma physics.

Dusty plasma is more complex as compared to normal electron–ion plasma, because it contains additional charged micron- or submicron-sized particles. This extra component of microparticles further increases the complexity of the system, so that it is also referred to as 'complex plasma'. Thus, dusty plasma is low-temperature fully or partially ionized electrically conducting gases whose constituents are electrons, ions, charged dust grains and neutral atoms. Dust grains can be massive and much more heavy than the protons, and their sizes are in the range from nanometers to millimeters. Dust grains may be metallic, dielectric, made of carbon, ice, etc., particulates.

Dusty plasma can be obtained, for example, as a result of combustion of a metal powder in the presence of some gaseous oxidizer. The product of burning contains finely divided particles of metallic oxides, whose size may vary

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